Final Report

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Application of Bifurcation Theory to the Dynamics of Flight at High Angles of Attack

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The chief purpose of this work has been to apply contemporary methods of bifurcation theory to the dynamics of flight at high angles of attack. Much of the effort was required to adapt continuation methods for computing the bifurcation curves of steady-state motions as control settings are changed. The complete system of nonlinear equations of motion for a rigid aircraft have been used, an eighth order system including the equations for two Euler angles. Special cases of a sixth order system (gravity ignored) and a fifth order system (when the speed is constant) are also accommodated.

Some results have been reported in References 1 and 2, but the entire program is thoroughly discussed in Dr. Jahnke's doctoral dissertation, Reference 3. We have nearly completed preparation of software to be made available to other parties. All the methods developed in this work have been incorporated on a disk for PC's. All of the examples analyzed to date are included, with provision for parametric changes as desired by the user. Examples are defined by the aerodynamic data; the software will allow users to provide their own aerodynamic models.

Three examples were treated in this work: a generic jet fighter (data from Reference 4), a general aviation canard design (longitudinal motions only); and the F-14 fighter. Bifurcations of steady states were determined and shown to cause instabilities leading to qualitative changes in the state of the aircraft. A longitudinal instability which resulted in a deep stall was determined for the general aviation aircraft. Roll-coupling and high angle of attack instabilities were determined for the F-14.

Knowledge of the control surface deflections at which bifurcations occurred was used to either put limits on the control surface deflections such that a combination of control surface

deflections at which bifurcations occur could not be attained. Simple control systems were included in the aircraft models to determine the effects of control systems on the instabilities of each aircraft. Steady spin modes were determined for each aircraft. A successful recovery technique was determined for the general aviation aircraft, but no successful recovery technique could be found for the F-14.

References

1. Jahnke, C. L. and Culick, F. E. C. (1988) *Application of Dynamical Theory to Nonlinear Aircraft Dynamics*, AIAA Atmospheric Flight Mechanics Conference, AIAA Paper No. 88-4372.

2. Jahnke, C. L. and Culick, F. E. C. (1990) *Application of Dynamical Systems Theory to the High Angle of Attack Dynamics of the F-14*, AIAA 28th Aerospace Sciences Meeting, AIAA Paper No. 90-0221.

3. Jahnke, C. C. (1990) *Application of Dynamical Systems Theory to Nonlinear Aircraft Dynamics*, PhD Dissertation, Department of Aeronautics, California Institute of Technology.

4. Young, J. W., Schy, A. A. and Johnson, K. G. (1980) *Pseudosteady - State Analysis of Nonlinear Aircraft Manoeuvers*, NASA TP No. 1758.